THE EYES OF THE BLIND VERTEBRATES OF NORTH AMERICA. VI.[1] THE EYES OF TYPHLOPS LUMBRICALIS (LINNÆUS), A BLIND SNAKE FROM CUBA.[2]

EFFA FUNK MUHSE.

Typhlops lumbricalis,[3] a blind snake, is generally distributed in the West Indies and Guiana. The specimens examined were obtained by Dr. C. H. Eigenmann in the neighborhood of Cañas, Province Pinar del Rio, Cuba. It is a burrowing form, that lives just beneath the surface, being thrown out even by the plow.

The snakes were first placed in formalin and after a few days were changed into alcohol. Only one young specimen was obtained, and it was preserved in Zenker's fluid. For decalcification, the heads of some were placed for at least three days in ten per cent. nitric acid and others in Perenyi's fluid from one to two weeks. One series was stained by the iron hæmatoxylin process, the others with hæmalum and eosin. It was very difficult to obtain satisfactory sections and especially complete series from the specimens, since no method was found to decalcify properly and to get the integument in condition for sectioning.

The lengths of the individuals examined were 10, 20, 21 and 21.5 cm. The color is brown above, on the ventral side it is yellowish-white. The body is covered with scales of uniform size, while those of the head are somewhat larger. The surface of the entire body is very smooth and shining and rather hard. The tail, which is about one twentieth of the body's length, ends in a short, sharp spine. The mouth is small and lies on the ventral side some distance back from the tip of the snout.

I. Normal Eyes of Snakes.

Snakes differ from other animals in having the edges of the two eyelids entirely grown together. A disk-shaped, conjunctival

[1] Contributions from the Zoölogical Laboratory of Indiana University under the direction of C. H. Eigenmann.

[2] The blind vertebrates of Cuba are rated with those of North America.

[3] Boulenger, G. A., "Catalogue of the Snakes in the British Museum," 1893.

sac is thus formed and the layers over the eye between this sac and the exterior form the "brille."

Six weakly developed muscles are present. The four straight ones arise in the neighborhood of the foramen opticus, while the two oblique ones arise from the surface of the prefrontal which is turned toward the eye socket.

Closely connected with the eye is a gland, Harder's, whose function is doubtful. Leading from this gland is a single duct, which either empties into the duct from Jacobson's gland or directly into the mouth cavity. The secretions of the gland are thus not functional in connection with the eye.

The sclera consists of closely woven fibers. Ciliary muscles are not found, but next to the iris is a great bundle of equatorial muscle fibers running obliquely, which seem to be a continuation of the iris musculature. The ciliary processes are weakly developed.

The retina consists of the usual layers. The nerve fiber layer is very thin (.003–.004 mm.).

The ganglion cell layer consists of a single, rarely two layers of small cells, each with a very large nucleus (.012–.013 mm.).

The inner reticular layer contains, at apparently regular intervals, elongated, oval nuclei (.042–.045 mm.).

The inner nuclear layer consists of two kinds of cells (.052–.054 mm.).

The outer reticular layer is very thin (.004–.005 mm.).

The sensory epithelium consists of the outer nuclear layer and the cone layer which is made up of single and twin cones. There are no rods. A single cone consists of two sections, an outer extremely small section, 5–6 microns in length and an inner much larger section, almost completely filled with a larger, pear-shaped, strongly refractive body, the ellipsoid, 14–16 microns in length and 8–9 microns across its widest part, which is turned toward the limiting membrane. The twin cone consists of two parts, one similar to a simple cone, the other cylindrical and very slender, its structure being otherwise like that of a simple cone. It is probable that the two parts of the twin cone are connected with but one nucleus. The nuclei of the cones vary greatly in form and leading from these into the inner layers of the retina are relatively very large fibers or processes.

Passing between the limiting membranes are the radial supporting Müllerian fibers.

II. The Eye of *Typhlops vermicularis.*

The work thus far on blind snakes has been done by Kohl on *Typhlops vermicularis*, a species found in Greece and the southwestern part of Asia, and on *Typhlops braminus*, a species found in the islands of the Indian Ocean and in Africa south of the equator, accounts of which are given in his "Rudimentäre Wirbelthieraugen."[1]

He found that in depth the eye of *Typhlops vermicularis* is equal to about one sixth that of *Tropidonotus.*

The brille is thicker in *Typhlops* than in *Tropidonotus* and, compared with the axial diameter of the respective eyes, is seven times thicker. In *Typhlops* the brille is equal in thickness to about one half that of the ordinary skin of the head. In *Tropidonotus* it is equal to one fourth.

The cornea of *Typhlops* measures .0052 mm., and compared with the relative sizes of the eyes is equal to about one half that of *Tropidonotus*, which measures .064 mm.

The conjunctiva is thickened at the edge of the disc-shaped sac and consists here of gland cells, the fornix conjunctiva.

The supporting membranes of the eyeball, choroid and sclera are relatively equal to about one half those of *Tropidonotus.*

Harder's gland in *Typhlops* is many times larger than the eyeball.

The six muscles are present.

The lens is elliptical, while that of *Tropidonotus* is almost globular. The ratio of the lens volume of *Typhlops* to the eye volume is 1 : 14.04, while in *Tropidonotus* it is 1 : 3.6. The lens epithelium of the former is relatively six times greater than that of *Tropidonotus.*

The retina at the back of the eye of *Typhlops*, and the retina of *Tropidonotus* bear the actual ratio of 8 : 13, while compared with the eye axis in each case the *Typhlops*-retina is four times greater. The fovea centralis and area are absent.

[1] Kohl, Dr. C. "Rudimentäre Wirbelthieraugen," Erster Thiel, Heft. 13, Bibliotheca Zoologica. Verlag von Theodor Fischer, 1892, Cassel.

The fiber layer has its greatest thickness near the exit of the nerve and gradually becomes thinner until, near the iris, scarcely a fiber is found.

The globular ganglion cells are arranged in a single layer except occasionally for short distances, when they lie in a double row.

The inner nuclear layer seems to be subdivided into four layers.

There are no twin cones. Each cone consists of a cone cell, stalk, middle and end members. The cone nuclei lie in two series, but the stalks vary in length so that the distal ends of the cone members reach nearly the same level.

III. The Eye of *Typhlops lumbricalis.*

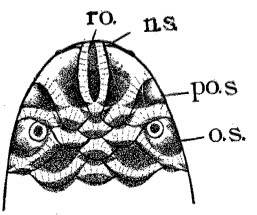
The eye shows through the large ocular scale, which entirely covers it. It appears as a black spot surrounded by an unpigmented circle. The preocular, also a large scale, overlaps the ocular and reaches just to the edge of the eye (Figs. 1 and 2).

General Account of the Eye.

Compared with one of the garter snakes and in proportion to the size of the head, the eye of *Typhlops lumbricalis* is located further from the surface and occupies far less space, while Harder's gland, associated with the eye in both, is relatively much larger in *Typhlops.* In a specimen of *Typhlops lumbricalis* 21 cm. in length, the eye measured .306 mm. in width, and .387 mm. in depth. The greatest width of the gland of the same was .711 mm. and the length was 1.067 mm. The gland completely surrounds the eye up to the edges of the conjunctival sac (Figs. 3 and 4). In proportion to the size of the eyes, the gland of a garter snake is much smaller than that of *Typhlops lumbricalis*, but compared with *Rhineura floridana*[1] the gland of *Typhlops lumbricalis* is but little more than half as large.

The eye is covered by layers of epidermis and dermis, that differ from these same layers on neighboring parts by being thinner, more compact and free from pigment and glands. The ocular scale, however, which covers the eye region, does not differ in thickness from the other scales of the head (Fig. 3).

[1] Eigenmann, C. A., "The Eyes of *Rhineura floridana*," *Proceedings of the Washington Academy of Sciences*, Vol. IV., pp. 533–548, Sept. 30, 1902.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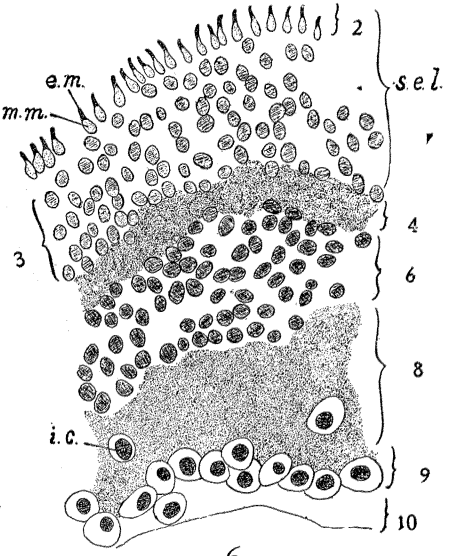
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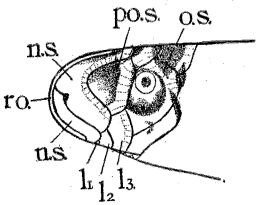
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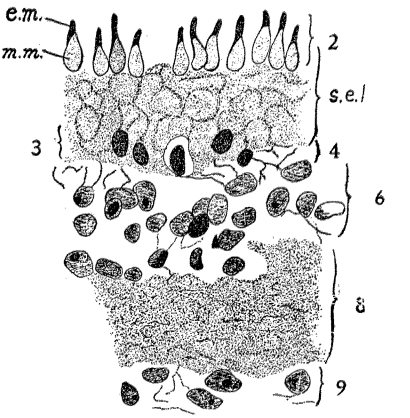
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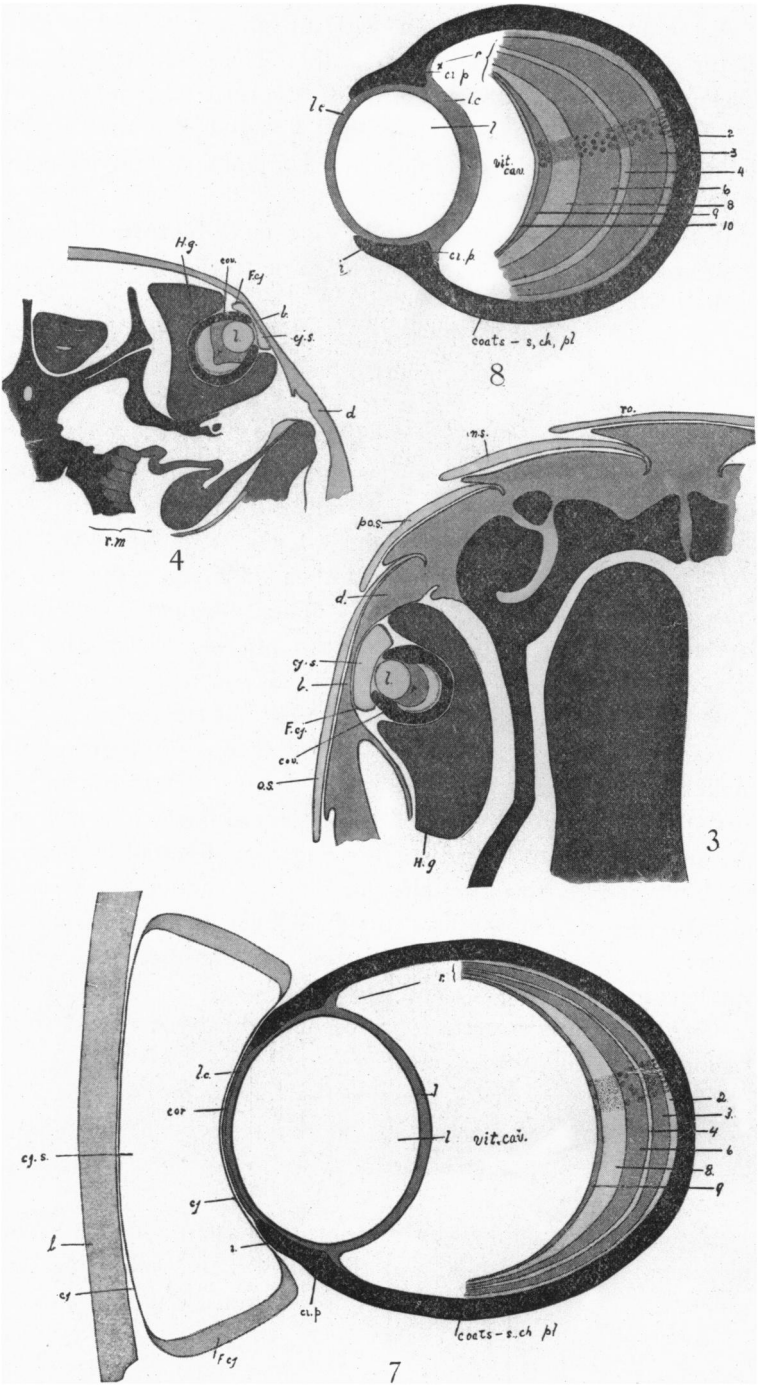
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A conjunctival sac is present with a diameter at least as great as the greatest width of the eye bulb. The conjunctiva, which forms this sac, is very thin over the cornea and next to the brille where it measures .003 mm. At the edge of the sac, it is differentiated into glands, the fornix conjunctiva, and measures .016 mm (Figs. 3 and 4).

In horizontal section, the eye axis is seen to be turned forward about 30° away from a line at right angle to the horizontal axis of the body.

Eye muscles are present, but from the sections used, the exact number could not be determined.

Minute Anatomy of Eye.

Choroid and Sclera. —The dense pigmentation makes it impossible to distinguish between the different coats at every point. Beyond the retina with its pigment layer is an open vascular space and this is followed by another dark layer, the two together representing the choroid. The choroidal pigmentary layer seems to consist of long fibers circularly arranged. The sclera can be followed by starting with the outer covering of the optic nerve and tracing its continuation about the eye.

Iris and Ciliary Processes. — Here again the pigmentation makes it difficult to determine the structure. Both iris and ciliary processes are present, for the black layer extends over the anterior surface of the lens, leaving a pupil equal in diameter to about one fourth of the circumference of the lens. At points near the equator of the lens this dark layer is enlarged into the ciliary processes and in connection with the capsule helps to hold the lens in place (Figs. 3 and 4).

Cornea. — This structure is present and can be traced to the region of the ciliary processes.

Lens. — A large lens is present, its depth being equal to about two fifths of the eye depth. From the sections little could be determined about its structure. A well-developed capsule surrounds it (Fig. 7).

Retina. — The same layers are present that are found in snakes in general, but the comparative thickness of the various layers is different. In the garter snakes, for instance, the retina is of a

uniformly even thickness even to the ciliary process, a single layer of cells continues on over the surface of the processes and iris, but in *Typhlops lumbricalis* the retina at the back of the eye is very thick and gradually becomes thinner till it ends a short distance from the ciliary processes (Fig. 7). At this point the arrangement could not be definitely determined in the sections. At the back the retina, exclusive of the pigment layer, measures .0725 mm.

Ends of fibers were seen projecting inward from the ganglion cell layer, but no definite fiber layer could be distinguished (10 in Fig. 5).

The ganglion cell layer (9 in the figures) consists of a single row of large nucleated cells, somewhat irregularly arranged (.008 mm.).

The inner reticular layer (8) consists of a mass of fibers interwoven in a close network. This layer measures, at the back of the eye, .015 mm.

The inner nuclear layer (6) consists of at least three layers of cells, loosely arranged. The course of some of the fibers can be followed among these cells. This layer measures .016 mm.

The outer reticular layer (4) is very thin and consists of a few fibers so arranged as to leave a great number of spaces between the two nuclear layers. The distance between the nuclear layers is about .005 mm.

The sensory epithelium shows two distinct parts, an inner layer of nuclei (3) and an outer row of cones (2). In the sections these two were so separated that a loose tissue was visible, consisting probably of the limiting membrane and ends of the Müllerian fibers. The outer nuclear layer in the adult consists of a single row of nuclei, with a mass of quite homogeneous material about them. This part of the sensory epithelium measures .018 mm. The cones are pear-shaped bodies with the smaller end pointing outward, and at intervals of every four or five a shorter one occurs. Each element is differentiated into two parts. By the iron hæmatoxylin process of staining, the outer small end is densely stained, while the body of the element is a light granular mass (Fig. 5).

The pigment layer (1) is a continuous layer of even thickness, similar in every respect to that of the garter snake.

One young specimen, 10 cm. in length, was examined. The eye as a whole, as well as the lens, is nearly spherical. The eye measures in width .290 mm. and .322 mm. in depth. All parts are so developed that the vitreous cavity is relatively much smaller than that of the adult. The coats are thicker, the ciliary processes better developed, the lens capsule thicker, and the retina at the back actually measures one and two thirds the depth of the adult retina. The elements of each layer are much more numerous than in the adult, and they are packed much more closely together (Fig. 6). The ganglion nuclei are apparently arranged one against the other. In the inner reticular layer occur the "interpolated cells." These were not found in the sections of the adult eye that were examined. The cells of the inner nuclear layer are smaller and arranged in five or six rows. There is a well-developed outer reticular layer similar in its make-up to the inner reticular. Instead of a single row of cone nuclei with its surrounding homogeneous mass, as in the adult, this layer in the young consists of five or six rows of small, closely arranged cells. The cones likewise are smaller and more numerous (Fig. 6).

COMPARATIVE MEASUREMENTS OF RETINAL LAYERS IN MM.

	Fiber Layer.	Ganglion Cell Layer.	Inner Reticular Layer.	Inner Nuclear Layer.	Outer Reticular Layer.	Sensory Epithelium.	Total Depth.
Tropidonotus natrix.	.003	.012	.042	.052	.004	.0196	.1331
Typhlops vermicularis.	.0018	.0081	.0155	.0221	.0022	.0324	.0821
Typhlops lumbricalis (adult).		.008	.015	.016	.005	.030	.0725
Typhlops lumbricalis (young 10 cm.).	.005	.010	.024	.032	.008	.040	.1206

RELATIVE PROPORTIONS OF EYE PARTS.

	Tropidonotus natrix.	*Typhlops vermicularis.*	*Typhlops lumbricalis* (adult).
Eye depth.	2.5541 mm.	.4399 mm.	.4032 mm.
Brille :	Eye axis :: 1 : 77.4	1 : 10.77	1 : 12.5
Cornia :	Eye axis :: 1 : 39.9	1 : 84.6	1 : 85
Lens depth :	Eye axis :: 1 : 1.56	1 : 3.03	1 : 2.5
Coats :	Eye axis :: 1 : 21.63	1 : 38.58	1 : 25.4
Retina at back :	Eye axis :: 1 : 19.19	1 : 5.36	1 : 5.5

Explanation of Figures.

Figs. 1 and 2 are from entire specimens. All figures except 1 and 2 are from sections. Figs. 7 and 8 are diagrams.

Explanation of Notations Used.

b. Brille.
ch. Choroid.
ci.p. Ciliary processes.
cj. Conjunctiva.
cj.s. Conjunctival sac.
cor. Cornea.
cov. Coverings of eye.
d. Dermis.
e.m. End member of cone.
F.cj. Fornix conjunctiva.
Hg. Harder's gland.
i. Iris.
i.c. Interpolated cells.
l. Lens.
l_1. First labial scale.
l_2. Second labial scale.
l_3. Third " " .
l.c. Lens capsule.
m.m. Middle member of cone.
n.s. Nasal scale.
o.c. Ocular scale.
p.l. Pigment layer.
po.s. Preocular scale.
r. Retina.
ro. Rostral.
r.m. Roof of mouth.
s. Sclera.
s.e.l. Sensory epithelium layer.
vit.cav. Vitreous cavity.

1. Pigment layer.
2. Cones.
3. Outer nuclear layer.
4. Outer reticular layer.
6. Inner nuclear layer.
8. Inner reticular layer.
9. Ganglion cell layer.
10. Fiber layer.

Fig. 1. Dorsal view of head of a specimen 21 cm. long.

Fig. 2. Lateral view of head of same specimen.

Fig. 3. Horizontal section of a specimen 20 cm. long, ⅔-objective, 2-inch eye piece, camera lucida.

Fig. 4. Transverse section of a specimen 21 cm. long, ⅔-objective, 2-inch eye piece, camera lucida. (Scales not shown.)

Fig. 5. Section of retina of an adult specimen 21 cm. long, $\frac{1}{12}$-objective, 1-inch eye piece, camera lucida.

Fig. 6. Section of retina of young specimen, 10 cm. long, $\frac{1}{12}$-objective, 1-inch eye piece, camera lucida.

Fig. 7. Diagrams of eye of adult.

Fig. 8. Diagram of eye of young.

(The region *x–r* in the sections could not be made out and is consequently left blank in the diagram.)